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Overview of the Manufacturing Engineering Toolkit Prototype

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Abstract

Many different types of manufacturing software applications have become available in recent years. These applications focus on specific engineering functions of the overall product life cycle. A problem facing industry is that these applications are not designed to work together and are difficult to integrate. A computer-aided Manufacturing Engineering Toolkit (METK) prototype is currently under development at the United States National Institute of Standards and Technology (NIST). The toolkit is being used to identify the integration standards and issues which must be addressed to implement plug-compatible environments in the future. The METK is a part of the Computer-Aided Manufacturing Engineering (CAME) program which is jointly sponsored by the U.S. Navy Manufacturing Technology program and NIST. The toolkit consists of commercial-off-the-shelf (COTS) manufacturing software applications housed together on a high speed computer workstation. The METK is envisioned to be an integration of these applications to support sharing of data between the applications. The purpose of the CAME project at NIST is to provide an integrated framework, operating environment, common databases, and interface standards for manufacturing engineering software applications. The current system includes a product data management application, a CAD application, a generative process planning application, and a suite of manufacturing simulation applications. This tool kit will be used in manufacturing data validation as a part of the overall product planning process required to manufacture a part. A demonstration of the toolkit applications has been prepared to illustrate the functionality of a prototype METK. The demonstration is comprised of two scenarios in which information in an engineering data package is generated and validated. This paper describes an initial METK prototype. Overall objectives of this effort include specification of integration interfaces and a methodology for manufacturing validation.

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Introduction

Hundreds of manufacturing engineering software applications have become available over the past decade. These applications can help manufacturing engineers perform the various tasks necessary to transform a product design to a physical reality. Currently these applications focus on specific engineering functions of the overall product life cycle. An issue facing industry today is that these applications are not intended to work together and can not be easily integrated. A solution to this problem would result in significant time savings in a product's life cycle.

A computer-aided Manufacturing Engineering Toolkit (METK) prototype is currently under development at the National Institute of Standards and Technology (NIST). The toolkit is being used to: 1) demonstrate that tools are commercially available to perform computer-aided manufacturing system engineering, 2) develop a better understanding for individual engineering tools and the overall environment, and 3) identify integration standards and issues which must be addressed to implement plug-compatible environments in the future. The METK is a part of the Computer-Aided Manufacturing Engineering (CAME) program which is jointly sponsored by the U.S. Navy Manufacturing Technology program and NIST. The toolkit consists of commercial-off-the-shelf (COTS) manufacturing software applications housed together on a high speed computer workstation. The METK is envisioned to be an integration of these applications to support sharing of data between the applications. See Figure 1 for a high level diagram of the proposed METK.

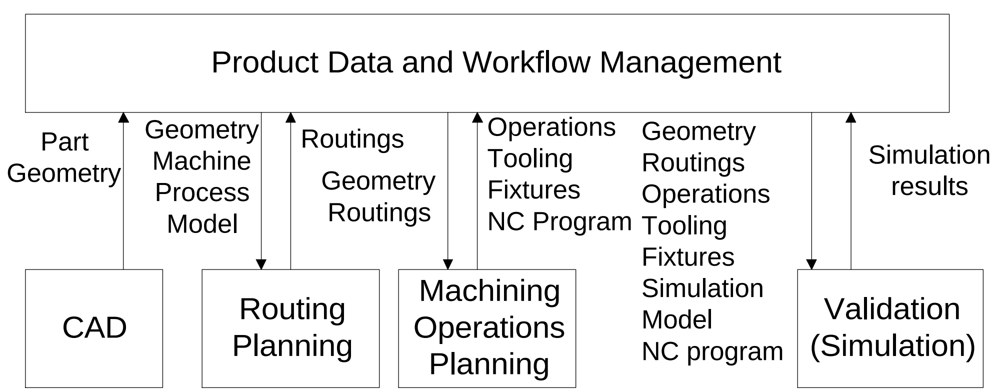

Figure 1 - Proposed METK System.

The purpose of the CAME project at NIST is to provide an integrated framework, operating environment, common databases, and interface standards for manufacturing engineering software applications. The goal is to lower manufacturing costs, reduce delivery times, and improve product quality through the use of advanced and integrated software tools. The METK focus is to develop an integrated toolkit that provides the following manufacturing functions: product data and workflow management, process planning, and engineering data validation using simulation. The functionality of the METK will be based on extensions to the capabilities of the commercial off-the-shelf applications included in the toolkit. The project is being conducted as a collaborative effort by users, vendors, academic researchers and representatives of other government agencies.

System

The METK prototype currently consists of the following software: 1) Adra Systems' Matrix (TM) is a product data management application, 2) Parametric Technology Corporation's Pro-Engineer (TM) is a CAD application, 3) Control Data's ICEM (TM) Part is a generative process planning application, and 4) Deneb Robotics Quest (TM) and Deneb Robotics VNC (TM) are manufacturing simulation applications used for data validation. An application to perform process routing will be added to the METK in a later version of the toolkit. See Figure 2 for a high level view of initial METK prototype.

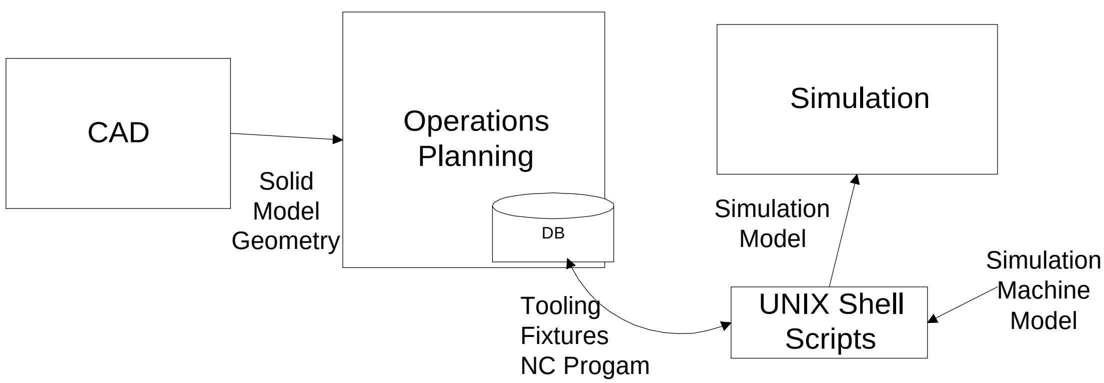

Figure 2 - Initial METK prototype.

Matrix (TM) from Adra Systems is an information management application. Matrix manages an object-oriented database of distributed information including documents, the applications that create the documents, and the processes that govern their life cycles. Matrix users can define objects using their own terminology. Users can then determine the states in an object's life, workflow patterns, and notification triggers that govern an object's behavior. Matrix is being used in the METK to implement a business process model of the manufacturing engineering functions. The business model of a product identifies the states a product passes through from design to production, the data associated with the product at each state, and the requirements for moving the product from state to state. This is what Matrix refers to as a policy. The policy ensures data integrity and proper information flow within an organization. Matrix also enforces version control of data at each state. Matrix version 2.0 is currently utilized in the toolkit.

Parametric Technology Corporation's Pro-Engineer (TM) is a CAD application that can be used to create product designs. Once the product is designed, a solid model geometry of the product and part blank can be output to data files. Pro Engineer version 13.0 is currently being utilized, but other CAD systems are envisioned to be integrated in later versions of the toolkit.

Control Data's ICEM (TM) Part is a generative process planning application. It uses a knowledge base of feature definitions, jigs/fixtures, machine tools, cutting tools, methods, and scenario information. ICEM Part accepts the CAD product design data files from Pro Engineer as input and uses the knowledge base to create a process plan for producing the product. This knowledge base is implemented in an Oracle (TM) database which can be modified by the user. Version 1.2.100 of ICEM Part is currently being utilized in the prototype toolkit.

Deneb Robotics Quest (TM) is a simulation application used for: analyzing production scenarios; product mixes and failure response for machines and labor; factory layout; throughput; and production costs. Deneb Robotics VNC (TM) is a simulation application for visualizing and analyzing the functionality of a machine tool, it's CNC controller, and the material removal process to optimize machining. Quest version 2.1 and VNC version 2.1 are currently being used in the toolkit.

These applications reside together and execute on a single UNIX based Silicon Graphics workstation. The workstation is configured as follows:

Onyx Extreme Deskside Workstation
- 200 MHz dual R4400 processor
- 128 megabyte RAM
- 4 megabyte secondary cache
- 2 gigabyte internal DAT tape drive
- 4 gigabyte SCSI-2 internal disk drive
- internal CD ROM
- dials and button box
- 21 inch Multisync Granite monitor.
- IRIX 5.3 operating system

This workstation is located in the Advanced Manufacturing Systems and Networking Testbed (AMSANT) facility at NIST. The facility was established to support testing of high performance computer and networking hardware in a manufacturing environment. The workstation is connected to the Internet and therefore capable of file transfer protocol (FTP) to accommodate transfer of data files from other sites participating in the project.

Demonstration

A demonstration of the toolkit applications has been prepared to illustrate the functionality of a prototype METK. The demonstration is comprised of two scenarios in which information in an engineering data package is generated and validated. An engineering data package contains the information needed to perform the manufacturing operations required to produce a part. The package contains various elements including NC programs, operations sheets, routing data, CAD models, tool lists, fixture lists, and machine lists. The engineering data package used in the demonstration is for a small prismatic machined part. The first scenario involves tasks performed to generate and validate the NC program, operation sheet, tool lists, and fixture lists elements of the engineering data package. The second scenario involves the validation of the routing data.

The first scenario of the demonstration consists of creating a solid model geometry in the Pro-Engineer CAD application. The CAD solid model geometry output is used as input into the generative process planning application ICEM Part. ICEM Part then creates a process plan and stores the information in the Oracle database. A CNC program is also produced by the ICEM Part application. Interface software is then executed to extract the machine tool, cutting tools, raw stock and fixture information from the database. This interface software was developed by Robert Judd, Ohio University under the Intelligent Machining Workstation project, see (1). This interface is currently implemented as UNIX shell scripts. The scripts query the Oracle database for the appropriate information, create the directory structure needed by Deneb VNC, and construct a simulated workcell in VNC. The workcell consists of: a pre-developed kinematic VNC model of the EMCO 100 milling workstation we are using in the demonstration; a blank fixtured to the machine table; geometric models of the tooling mounted on the machine; and the appropriate CNC program. See Figure 3 for a depiction of the EMCO 100. The demonstration then executes Deneb VNC to simulate the machining process. VNC is used to help identify any errors in the CNC program as well as any tool crashes or part gouges. This is a major part of the NC program validation process.

The product to be manufactured is a small rectangular prismatic workpiece with over thirty manufacturing features or patterns of topology and geometry. The features consist of holes, notches, slots and pockets. The workpiece material is plastic. In ICEM Part, features are volumes of the workpiece to be removed by a sequence of machining operations. ICEM Part recognized all features of the product. ICEM Part specifies setups, machining operations, tooling, and the tool paths necessary to manufacture the product. In this case, ICEM Part specified two setups using shank end mills, machine taps, a twist drill and a center drill for machining.

The simulation workcell model was run in Deneb VNC and a collision occurred between the tool holder and the workpiece. The collision happened when the 1/4 inch twist drill was machining two of the holes on the workpiece. The holes are recessed in a pocket that is not wide enough to accommodate the width of the toolholder holding the 1/4 inch drill. See Figure 4 for a depiction of the workpiece, 1/4 inch drill, and toolholder. The toolholder is located in the upper right of the figure with the 1/4 inch drill extending down from it towards the workpiece.

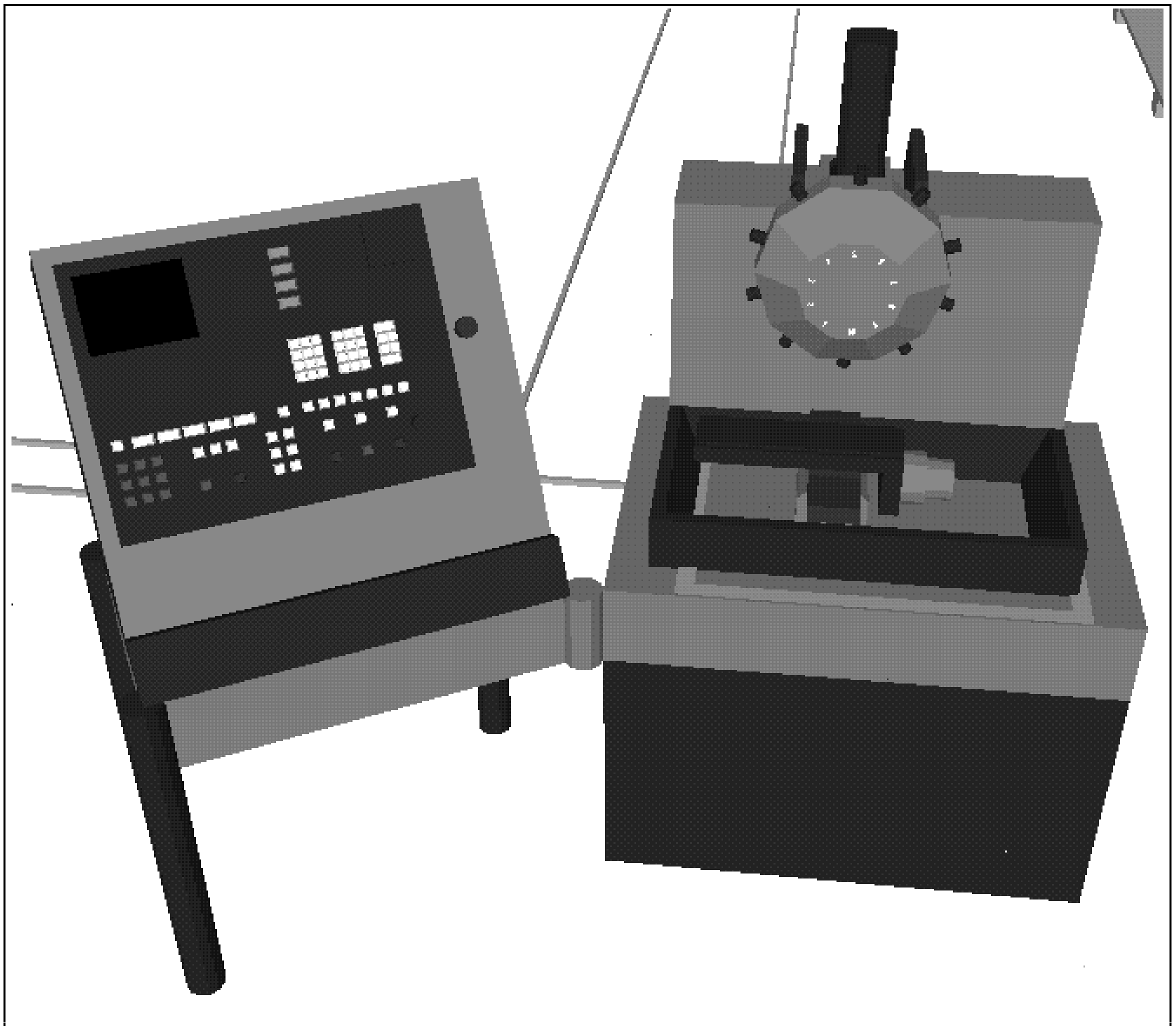

Figure 3 - EMCO 100 Vertical Milling Machine

ICEM Part is executed again to revise the process plan. This time the user manually overrides the two setup specification and specifies three setups to machine the workpiece. The third setup has the workpiece flipped over so the holes that caused the collision in the two setup process plan could be drilled from the underneath of the piece. The three setup process plan data is generated and stored. The interface software is executed and the new process plan data is translated to the Deneb VNC workcell model. The manufacturing simulation is executed with three setups and the product is manufactured correctly in the simulation.

This emphasizes a key point the METK project is trying to get across in the context of data validation, the integrated toolset of software applications cross-check each other for consistency and accuracy. This will help ensure that in the end, a better, more reliable engineering data package hits the machine shop floor the first time. The result should be that the real life workpiece can be successfully machined the first time thereby reducing the time and money expenditure for producing the machined part.

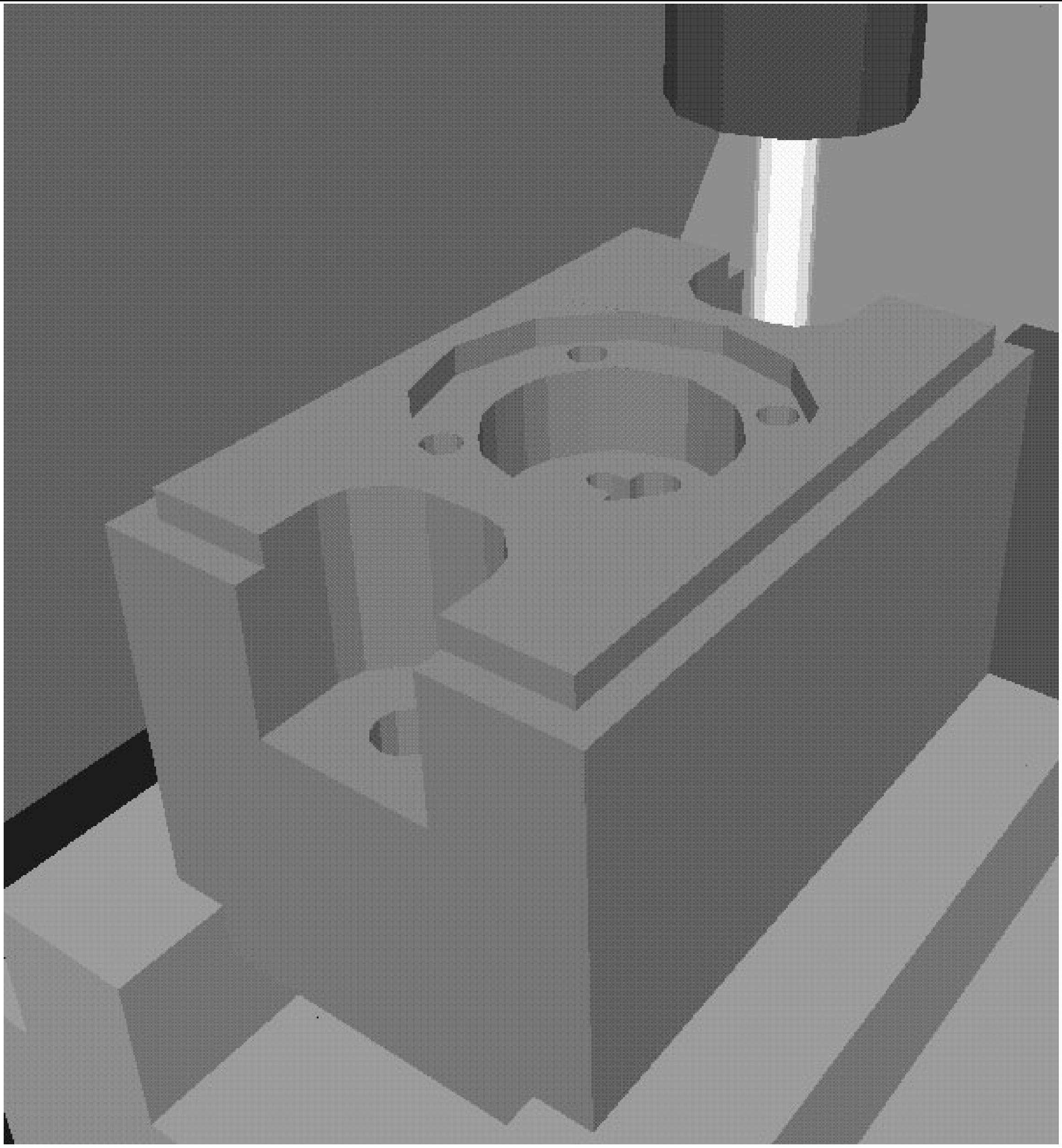

Figure 4 - Workpiece, 1/4 inch twist drill, and toolholder.

The second scenario of the demonstration simulates the workflows between factory workstations used to create the prismatic product. A virtual factory is being modeled in Deneb Quest. Each workstation in the virtual factory will perform processes that represent manufacturing processes. The processes were selected by industrial participants at the first technical meeting of the Computer Aided Manufacturing Engineering Forum on March 21-22 1995, see (2). The inclusion of additional workstations in the virtual factory which perform other types of processes will be considered as the needs of the forum participants change over the life of the project. The Quest model development has focused on the workflow/routing required to produce the prismatic product used in the first scenario of the demonstration. The Quest simulation environment is intended to validate the routing data in the engineering data package.

The virtual factory being modeled in Deneb Quest currently consists of the following manufacturing areas: tool room, shipping, receiving, heat treat, paint, manufacturing/engineering/administrative offices, and three machining areas. The tool room contains a tool assembly station, a fixturing station, tool crib, and a shop floor supervisor's office. The shipping/receiving areas have raw storage, tables, a scale, a bandsaw and forklift. The heat treat area contains two ovens. The paint area contains paint tanks, a paint robot under a paint hood, and pallets. Area 1 contains three EMCO 100 vertical milling machines that are used to machine the prismatic part we are manufacturing in the demonstration. Area 1 also contains a parts washer, two Mandelli horizontal vertical mills, three T30 Cincinnati Milacron milling machines, a coordinate measuring machine (CMM), tables and pallets. Area 2 contains two lathes, three grinders, and a finisher. Area 3 contains a laser cutter/punch, a laser punch, a press bender, bandsaw, drill press, jigbore, and a belt sander. See Figure 5 for a depiction of the three EMCO 100 milling machines as they sit on the virtual factory floor. The concentration during development of the virtual factory has been to model the workflow required to produce the prismatic product used in the demonstration. The workflow model was generated using the Quest user interface. In later versions of the toolkit, the routing data will be generated by a routing planning application. The routing data would then be validated in the Quest simulation application. The Quest model in the demonstration simulates the following workflow between workstations:

1. Raw bar stock arrives at the receiving area.
2. The raw bar stock is cut in receiving by a bandsaw.
3. The cut stock is loaded in a box and forklifted over to area 1 for machining.
4. The cut stock is unboxed and loaded on the vertical milling EMCO 100 workstations (One workstation for each setup required to machine the product as specified by the ICEM Part generative process planning application).
5. After the products have been machined, they are boxed and sent on to the remaining workstations in the workflow:
6. CMM for quality assurance and gauging. Then washing, heat treating, painting, and shipping.

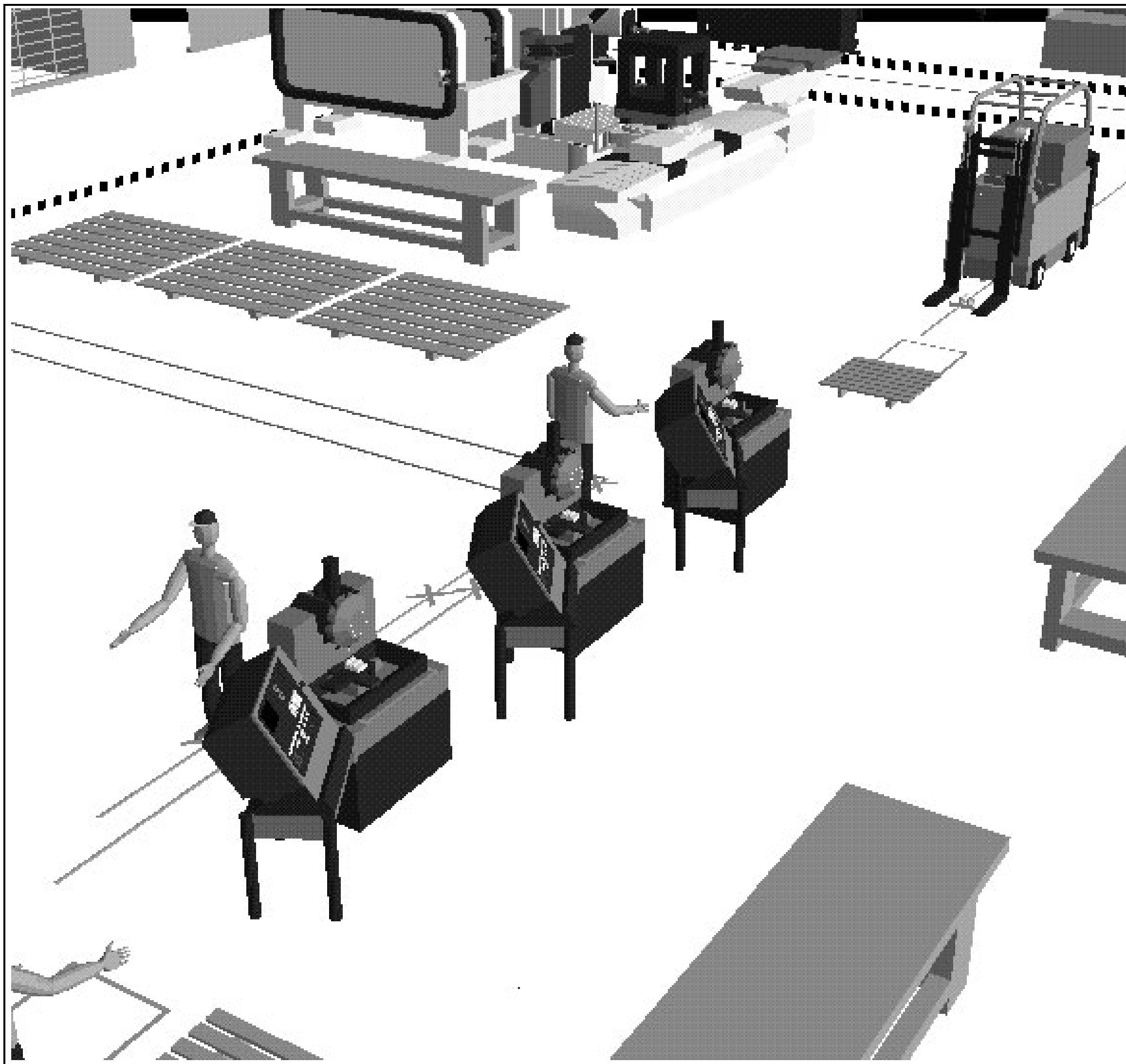

Figure 5 - Three EMCO Vertical Milling machines as they reside on virtual factory floor.

Summary

This paper described an initial METK prototype currently under development at NIST. The METK prototype will help identify integration problems existing between manufacturing applications that prevent data sharing. It will also help develop a better understanding and further identify functional requirements for the individual manufacturing applications. Once these integration issues are identified, they can be addressed and technical solutions can then be proposed. One issue is that the input data from one manufacturing application must be able to be input to subsequent versions of the same application, i.e., provide upward compatibility. If data is generated for a particular version of an application, that data should not be thrown away, it should be able to be used in later versions of the application. Another issue is data format. If an application generates data in a specific format, will that format be readable by other applications in the toolkit.

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